APPENDIX B

DESIGN EXAMPLES

B-1. General. Both magnitude and repetitions of loading are significant parameters in pavement design. Highway designers have long been plagued with these parameters, further complicated by the variety of loadings to be accommodated. However, means have now been developed for expressing the relative effect of any particular loading in terms of operations of a basic loading. This permits integration of the gross effect of any array of loadings in terms of equivalent operations of a basic loading, which in turn permits treatment of traffic intensities directly. Typical arrays of traffic for a range of maximum loadings and of intensities of use have been treated, in the manner indicated above, to reduce them to an equivalent in terms of repetitions of a basic 18,000-pound, single-axle, dual-tire load. These have in turn been reduced to the design-index values tabulated in table 5-1, paragraph 5-2.c. To illustrate the selection of a design index, assume that the design index is desired for a Class B street to support traffic including about 10 percent three-, four-, and five-axle trucks. This is a Category IV loading according to the criteria established in paragraph 5-2.b., and using the Class B designation, a design-index value of 5 is obtained from table 5-1, paragraph 5-2.c. To illustrate selection of a design index when tracked vehicles are involved, assume that the street in the example above must, in addition to the traffic indicated, sustain the operation of tanks having a gross weight of 80,000 pounds. Paragraph 5-2.c. shows that this is provided for by design index of 6.

B-2. Compaction requirements. An example of the application of the compaction requirements shown in figure 3-1 is given here. Assume a design is required for a design index of 5.

a. Base course. Materials meeting the specifications for base course can usually be compacted to more than 100 percent of maximum density. Assume that previous experience or a test section showed that while maximum density for the processed sample was approximately 143 pcf, field densities on total samples were all more than 150 pcf when compacted with eight coverages of a heavy rubber-tired roller. In this case, the requirement should be specified as 105 percent maximum density.

b. Subbase. Subbase compaction requirement would be specified as 100 percent of maximum density unless the subbase is a sandy gravel, gravel, or rock, in which case it is probable that 100 percent would be obtained with relatively little field compaction. In this case, a higher value, based on previous experience or a test section, should be specified. For the remainder of the example, two subgrades are used to illustrate the application of the data.

c. Cohesionless ($PI\leq5$; $LL\geq25$) subgrade. Assume a clean cohesionless sand and a design CBR of 20, with a natural in-place density of 90 percent of maximum density to beyond the depth of exploration (6 feet). A minimum of 100 percent of maximum density is required at the top of this material unless, as explained in the preceding paragraph for subbase, a higher value is readily obtainable. From figure 3-1, it is found that this 100 percent must extend to a depth of 11.5 inches below the pavement surface. Below this depth, fill sections must be compacted to 95 percent maximum density throughout, and cut sections to 95 percent of maximum density to a depth of 20 inches below the pavement surface. The designer must decide from previous experience or from test-section data whether or not these percentages of compaction in cut sections can be obtained from the top of the subgrade. If they cannot, a part of the subgrade must be removed, the underlying layer compacted, and the material replaced, or the thickness of select material or subbase must be so increased that the densities in the uncompacted subgrade will be adequate.

d. Cohesive ($PI>5$; $LL>25$) subgrade. Assume a lean clay, a design CBR of 7, and a natural in-place density of 80 percent of maximum density extending below the depth of exploration (6 feet). For this example it is assumed that with the soils involved and the type of equipment available, compaction of the subgrade from the surface would be impracticable beyond the 6- to 8-inch depth that could be processed; therefore, the minimum depth of cut would be limited by the in-place density. From figure 3-1, it is found that the 80 percent in-place natural density would be satisfactory below depths of about 26.5 inches from the pavement surface. From CBR design curves (explained subsequently), the top of the subgrade will be 13 inches below the pavement surface; therefore, a zone 13.5 inches thick below the top of the subgrade requires treatment. The bottom 6 to 8 inches of this can be processed in place; so about 6 inches of material must be removed and replaced. Compaction to 95 percent of maximum density is required for all cohesive material that lies within 13 inches of the pavement surface. Since the subgrade does not fall within this zone, compaction requirements in the replaced material and in the layer processed in place should be 90 percent of maximum density to conform to fill requirements. Compaction requirements for the subgrade will therefore be 90 percent for the top 13 inches, the first lift of which can be processed in place.

B-3. Thickness design by CBR method. To illustrate the analysis of design by the CBR method when the subgrade, subbase, or base course materials are not affected by frost, or when detrimental settlement or conditions requiring special treatment are not the principal consideration in design, assume that a design is to be prepared for a road that will require a design index of 5. Further assume that compaction requirements will necessitate an increase in subgrade density to a depth of 7 inches below the subgrade surface and that a soft layer occurs within the subgrade 21 inches below the subgrade surface. The CBR design values of the various subgrade layers and the materials available for subbase and base course construction determined by the methods described in previous paragraphs and shown in table B-1 are as follows:

Table B-1. CBR Design Values

Material	Soil Group Unified Soils Classification System	Design CBR
Weak layer in subgrade	CH	3
Natural subgrade	CL	5
Compacted subgrade	CL	7
1	GP	35
2	GM (Limerock)	80

The total thickness and thicknesses of the various subbase and base layers are determined as follows.

a. Total thickness. The total thickness of subbase, base, and pavement will be governed by the CBR of the compacted subgrade. From the flexible-pavement design curves shown in figure 5-1, the required total thickness above the compacted subgrade (CBR of 7) is 13.5 inches. Next, a check must be made of the adequacy of the strength of the uncompacted subgrade and of the weak layer within the subgrade. From the curves in figure 5-1, the required cover for these two layers is found to be 17.0 and 23.5 inches, respectively. If the design thickness is 13.5 inches and the subgrade is compacted to 7.0 inches below the subgrade surface, the natural subgrade will be covered by a total of 21.5 inches of higher strength material. Similarly, the soft layer occurring 21.0 inches below the subgrade surface will be protected by 34.5 inches of total cover. Thus, the cover is adequate in both cases.

b. Minimum base and pavement thickness. For a design index of 5 the minimum base thickness is 4.0 inches and the pavement thickness is 2.5 inches as indicated in table 3-1. If, however, the CBR of the base material had been 100 rather than 80, a minimum pavement thickness of 2 inches would have been required.

c. Thickness of subbase and base courses. The design thickness of each layer of materials 1 and 2 will depend upon the CBR design value of each material. Figure B-1 herein shows two combinations chosen to illustrate the design procedures. Final selection of the section to be used will be based on the economics of its construction. Figure B-1(a) shows a design using both materials. The total thickness of subbase, base, and pavement, as determined in a above, is 13.5 inches. The thickness required above material 1 (CBR = 35), as determined from figure 5-1, is 3.5 inches; therefore, the required thickness of material 1 is 10.0 inches (13.5 - 3.5 inches). The 3.5-inch layer required above material 1 will be composed of material 2 and pavement; however, adjustments must be made in the thicknesses of material 2 and the pavement to conform with minimum base and pavement thicknesses given above, which is a combined thickness of pavement and base of 6.5 inches (2.5 inches of pavement and 4.0 inches of base). Therefore, the section using materials 1 and 2 will consist of a 7.0-inch subbase course of material 1, a 4.0-inch base course of material 2, and a 2.5-inch pavement, as shown in figure B-1(a). Figure B-1(b) illustrates a simple design using material 2 only. The total thickness of 13.5 inches is composed of 2-1/2 inches of pavement and 11.0 inches of material 2.

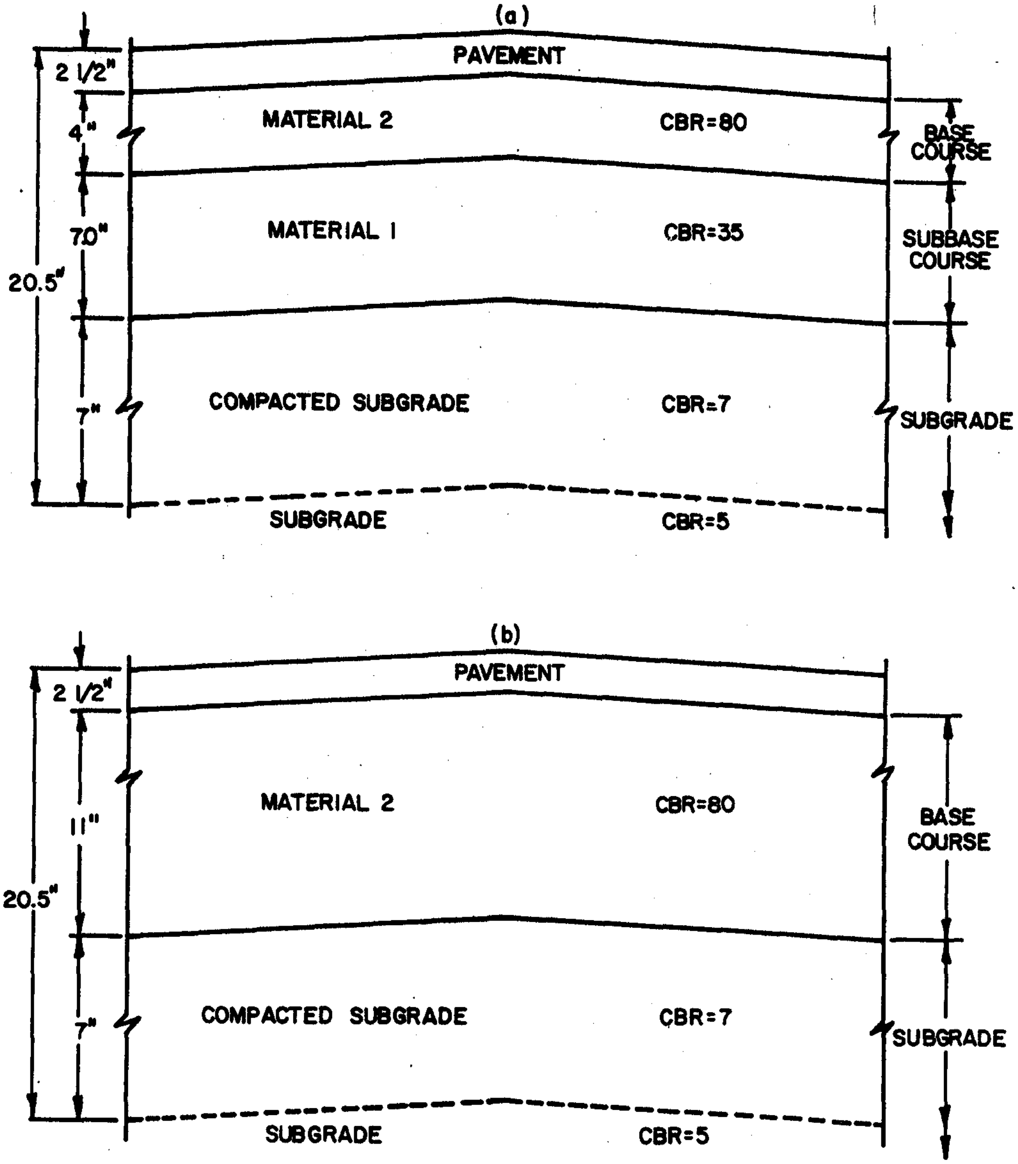
d. Cost comparison. A careful cost comparison would be needed to establish whether the design shown in figure B-1(a) is more economical than that shown in figure B-1(b) since the cost of material 1 would rarely approach the cost of material 2. These examples show that CBR method of design allows rapid investigation of the possibilities of economizing by using locally available materials.

B-4. Determination of subbase CBR values. For an example, suppose that five types of material are available for subbase course construction at a particular site and the CBR design value to be used for each of these materials is desired. Assume also that the necessary testing has been performed on each of these materials with the results shown in table B-2.

Table B-2. Material Types and Design Values

Test	Caliche	Silty Sand	Gravelly Sand	Sandy Gravel	Gravel
CBR (laboratory)	100	14	35	45	65
Maximum size, inches	1.5	0.06	0.5	1.0	2
Percentage passing No. 10 sieve	42	100	85	35	20
Percentage passing No. 200 sieve	10	20	14	6	3
Liquid limit	31	14	12	11	10
Plasticity index	10	2	3	NP	NP
CBR design value	20	14	30	45	50

The CBR design value for the caliche is 20 because the liquid limit and plasticity index are higher than those allowed (see table 2-1) for greater CBR design values. The CBR design value for the silty sand is 14 because this is the value determined by the CBR penetration test and no other limitations apply. If the laboratory CBR value had been greater than 20, the CBR design value would have been restricted to 20 because 15 percent is the maximum amount of material passing the No. 200 sieve permitted for higher CBR values and this material had 20



U. S. Army Corps of Engineers

FIGURE B-1. DESIGN EXAMPLE, CLASS B STREET CATEGORY IV, LOADING DESIGN INDEX 5 percent passing. The CBR design value for the gravelly sand is 30, because 80 percent is the maximum amount of material passing the No. 10 sieve permitted for higher CBR values and this material had 85 percent passing. The CBR design value for the sandy gravel can be a maximum of 50 since it meets all the requirements of the limiting specifications, and it is therefore 45 as determined by the CBR penetration test. The CBR design value for the gravel is 50 since it meets all specification limitations for subbase and cannot qualify as a base course material.